I. C. 7500 MAY 1949

UNITED STATES
DEPARTMENT OF THE INTERIOR
J. A. KRUG, SECRETARY

BUREAU OF MINES
JAMES BOYD, DIRECTOR

INFORMATION CIRCULAR

PROSPECT DRILLING FOR PHOSPHATES IN FLORIDA

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JOHN C. FEELEY, JR.

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UNITED STATES DEPARTMENT OF THE INTERIOR - BUREAU OF MINES

PROSPECT DRILLING FOR PHOSPHATES IN FLORIDA[1]

By John C. Feeley, Jr.[2]

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[1] The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from Bureau of Mines Information Circular 7500."

[2] Mining engineer, Bureau of Mines, United States Department of the Interior.

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INTRODUCTION

This paper is the result of a field study of prospect drilling in the Florida phosphate fields. The objective is to describe the drilling methods employed.

Since the general policies of the operating companies in the land-pebble area do not permit the dissemination of prospecting information and costs thereof, the writer has carefully avoided mentioning names and locations except by reference to existing publications.

ACKNOWLEDGMENTS

The Bureau of Mines, through its Mining Division, Lowell B. Moon, chief, has as its primary objective the more effective utilization of domestic mineral resources. It recognizes the value of dissemination of pertinent information relative to the technical development of prospect drilling.

This report was prepared under the immediate supervision of J. R. Thoenen, chief, Tuscaloosa Branch, Mining Division.

Thanks are expressed to the managers and engineers of the operating companies for prospecting information and privileges extended to the writer, which were essential to the preparation of this paper.

LOCATION

Phosphate occurrences in Florida are divided into the "pebble field" and "the hard-rock field" (fig. 1).

The Florida pebble field, as it has come to be known, comprises an area (fig. 2) within a radius of about 18 to 20 miles centering around Mulberry in Polk County.[3]

The Florida hard-rock field extends from Suwannee and Columbia Counties in northwest Florida to south of Croom, Fla., in Hernando County. This area is approximately 100 miles long and varies from 2 to 30 miles in width[4] (fig. 1).

---

[3] Fulton, Chester A., Mining Practice in the Florida Pebble Phosphate Field: Am. Inst. Min. and Met. Eng., Tech. Pub. 662, 1936, p. 3.

[4] Kibler, D. B., Jr., Mining and Preparation of Florida Hard-rock Phosphate: Am. Inst. Min. and Met. Eng., Tech. Pub. 1315, 1941.

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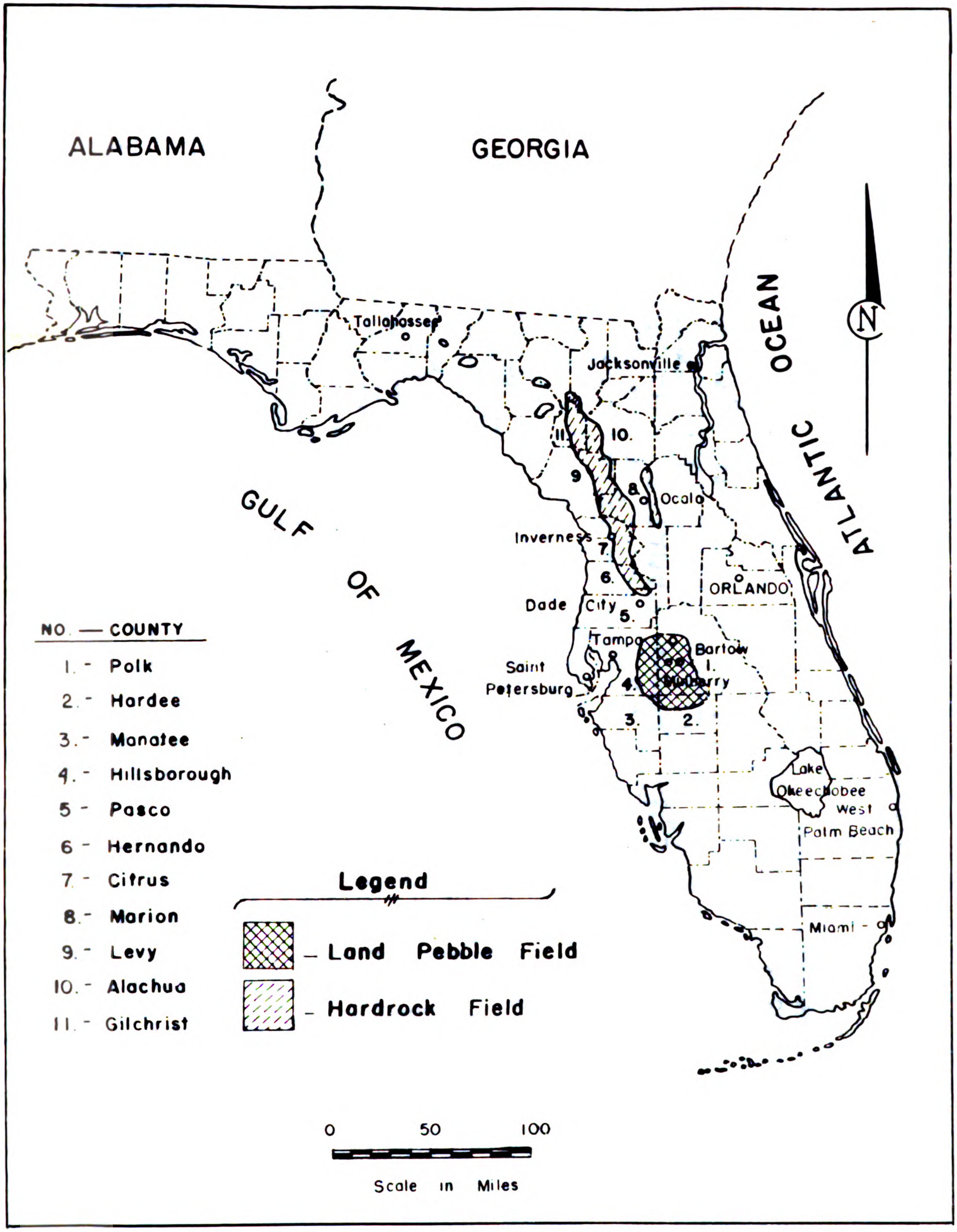


Figure I. - Index map, State of Florida.

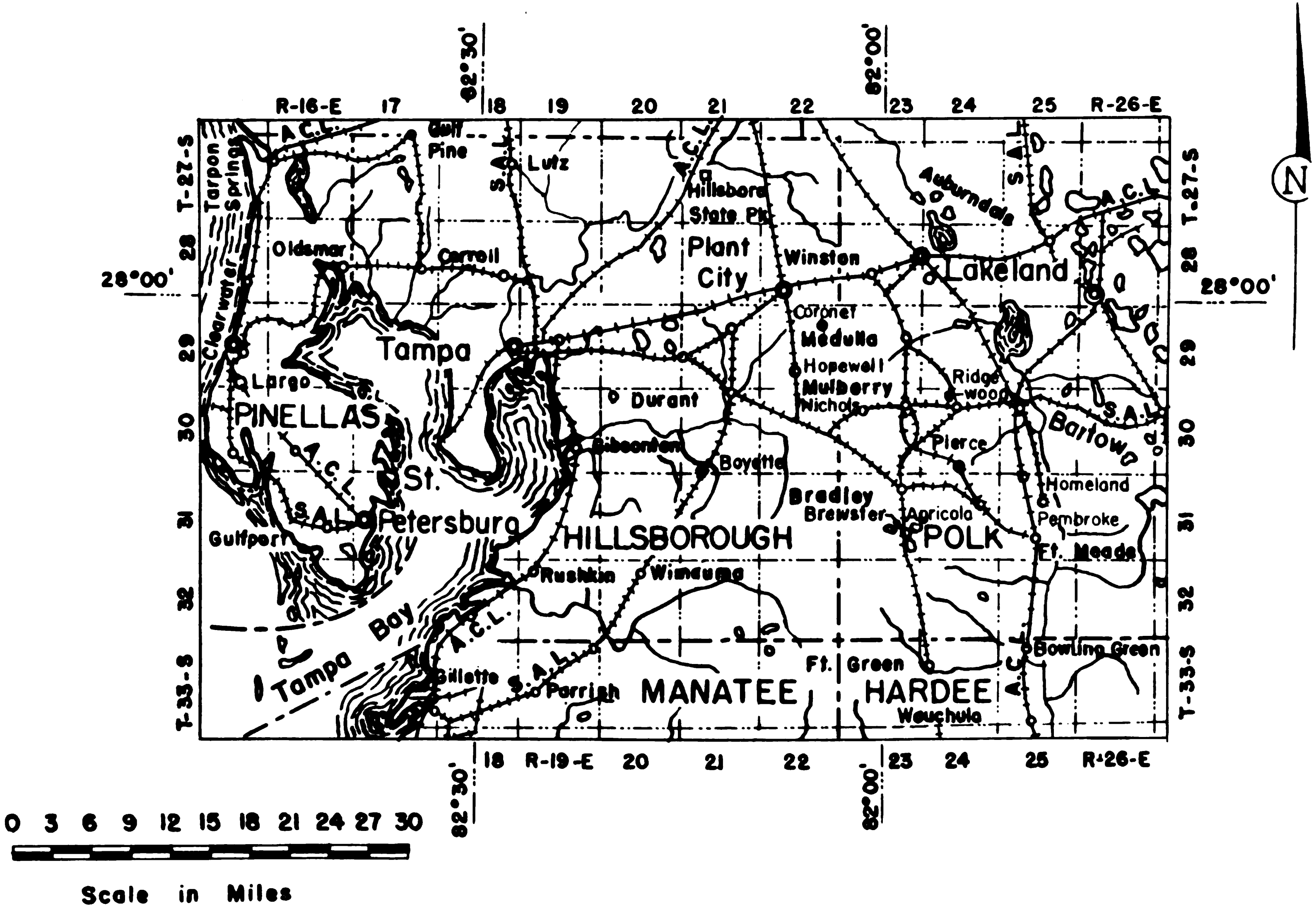


Figure 2. - Map of land-pebble field, Florida.

TOPOGRAPHY

The topography of the land-pebble and hard-rock fields embraces low-lying swampy areas, lakes, flat areas, gentle sloping plains, and low-rolling hills. The elevation ranges from about 60 to 175 feet above sea level.

HISTORY

Land-Pebble Field

Phosphate pebble occurrences are reported to have been discovered on the Peace River, Polk County, in 1885[5].

The many small operations have long since disappeared, and the most desirable phosphate lands have gradually been acquired through purchase or merger by seven operating companies, listed as follows:

International Minerals & Chemical Corp., Florida Phosphate Division, Mulberry, Polk County.

Davison Chemical Corp., The Phosphate Rock Division, Ridgewood, Polk County. (Formerly Southern Phosphate Co.)

American Cyanamid Co., Brewster, Polk County.

Phosphate Rock Mines, The American Agricultural Chemical Co., Pierce, Polk County.

Swift & Co., Fertilizer Works, Agricola, Polk County.

Virginia-Carolina Chemical Corp., Nichols, Polk County. (Formerly Phosphate Mining Co.)

Coronet Phosphate Co., Coronet, Hillsborough County.

Pembroke Chemical Corp., Pembroke, Polk County (inactive in September 1947).

Hard-Rock Field

Florida hard-rock phosphate was discovered at Hale Springs, about 1 mile northwest of the town of Dunnellon, Marion County, in the year of 1888, by Albertus Voight,****.

The hard-rock deposits are more irregular and have higher mining costs than the pebble-rock deposits, therefore they have not been competitive in the domestic market, but because of *** higher grade*** it is in demand for export trade.[6]

---

[5] Fuller, R. B. (manager, Florida Phosphate Division, International Minerals & Chemical Corp.), Industrial Faith in Florida: 1939-43, p. 5 (pamphlet).

[6] See footnote 4, p. 2.

During 1947 the Section 12 mine, owned by C. & J. Camp, Inc., and J. Buttgenbach & Co., about 3 miles southeast of Dunnellon, Citrus County, was the only active mining operation in the field (fig. 3). Other companies limited their operations to re-treatment of old debris or tailing dumps left from previous operations.

MINING

Phosphate is mined in Florida by open-pit methods. In the land-pebble field, large electrically operated draglines are employed to strip overburden and mine the matrix; only two hydraulic operations remain in the district. Mining in the hard-rock field consists of removing the overburden with hydraulic methods and mining the rock with draglines.

GEOLOGY

Land-Pebble Field

The deposits comprise flat-lying, unconsolidated, sedimentary beds as described in the following table 1, after Roundy.[7]

Hard-Rock Field

The hard-rock field in those parts of Marion and Citrus Counties where wells were drilled contains four sets of deposits that affect phosphate explorations. At the top lie such recent materials as soil, silt, and windblown sand, and below are the Alachua formation, the Suwannee limestone (present only in a small area) and the Ocala limestone.[7]

Phosphate

Land-Pebble Field

Physically the phosphate-bearing formation, locally called "matrix" varies in thickness from nothing to about 25 feet, usually averages 10 feet, and consists mainly of clay, quartz [sand] and phosphate pebble, the latter particles varying in size from colloidal to one-inch diameter. The pebbles range in color from [black] dark gray, through white to cream, and in hardness from that which must be broken with a hammer to that which can be scratched with the fingernail. They assay from 66 to 80 percent bone phosphate of lime (called "B.P.L." in the trade) or tricalcium phosphate ($Ca_3P_2O_8$) and are secondary apatites. They form from 15 to 50 percent by weight of the matrix. Over the matrix lies a varying thickness (5 to 40 feet) of overburden composed of quartz [sand] and clay.[8]

---

[7] Roundy, P. V., Phosphate Investigation in Florida, 1934-35: Geol. Survey Bull. 906-F, 1941, p. 271

[8] Pamplin, J. W., metallurgist, Southern Phosphate Corp., Bartow, Fla., Ore Dressing Practice with Florida Pebble Phosphate, Southern Phosphate Corp.: Am. Inst. Min. and Met. Eng., Tech. Pub. 881, February 1938, p. 1.

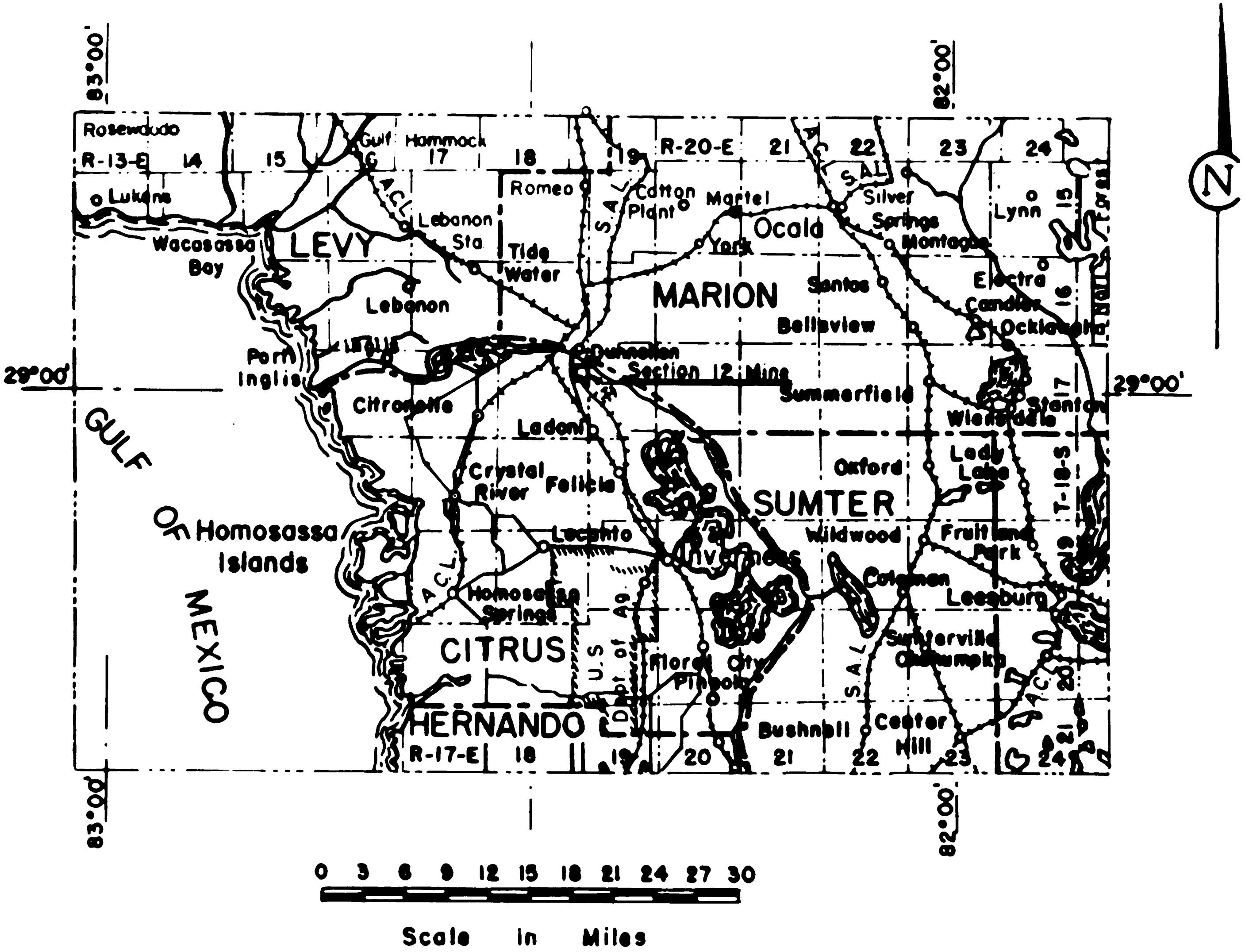


Figure 3. - Map covering portion of hard-rock field, Florida.

TABLE 1.*- Correlation of deposits in land-pebble area with prospector's divisions
(Thicknesses are those obtained from test wells)

Prospector's divisions		Lithologic character	Formation	Series	System
Over-burden 3-1/2 to 98 feet	0 to 27 feet	Wind-blown sand, soil, sand, silt, muck, sandy clay, and peat.		Recent	Quaternery
		Sand, hardpan		Recent or Pleistocene	
	0 to 79 feet	Sand, sandy clay, clay	Citronelle (?) formation	Pliocene	Tertiary
	0 to 19 feet	Black to dark greenish-gray clay with very fine mica flakes.	Probably marginal phase of Bone Valley gravel.		
Phos-phate deposit (0 to 28-1/2 feet)	Phos-phate beds (0 to 24-1/6 feet)	Phosphate pebbles in sand, sandy clay, or clay matrix, with or without some barren beds.	Bone Valley gravel		
	Bed clay (0 to 9-1/2 feet)	Soft clay, with or without phosphate pebbles and without sand			
Barren beds, (0 to 19-1/2 feet)		Sand, sandy clay, or clay, without phosphate or with only a few scattered minute phosphate pebbles. Occurs between lowest important phosphate deposit and top of soft or hard bedrock.	Probably lower part of Bone Valley gravel. (May contain some material in bottom equivalent to soft bedrock.)		
Soft bedrock (0 to 11 feet)		Soft clay with strong lime reaction. Locally some sand but not as distinct sand beds. Usually shows slight amount of phosphate on chemical test.	Hawthorne formation. (In a few wells the limestone may be Tampa limestone)	Miocene (lower)	
Hard bedrock		Hard limestone			

* See footnote 7, page 4.

According to Fulton

> The Matrix varies in thickness from nothing to 40 feet. Profitable mining usually requires that the matrix bed be at least 6 feet thick, and generally it is not thicker than 25 feet. In exceptional instances, the overburden is only a few feet deep, usually 15 to 25, while 50 feet, is close to the limit for profitable operation.[9]

Hard-Rock Field

> The phosphate in the hard-rock area occurs mainly as boulders of rather high-grade phosphate. These are of different sizes, some weighing several tons. Their distribution is very irregular. In some places they are segregated in large masses in an area of several acres, with adjacent areas barren. Elsewhere they may occur in long, irregular-shaped areas, connected or nearly connected and covering many acres.--------. Flint boulders, pebbles of flint, phosphate, and other materials with powdered phosphate may occur with or near the phosphate boulders.[10]

PROSPECTING METHODS

Prospecting is restricted to some form of drilling methods. Drilling serves a twofold purpose: (1) To discover and outline phosphate deposits and (2) to secure accurate samples that are used as a basis for operation and production estimates.

Land-Pebble Field

The average depths of holes range from about 30 to 50 feet, although some holes have been drilled to between 70 and 90 feet.

Drilling Pattern

The general drilling pattern used in the district is shown in figure 4. Complete sampling of a 40-acre tract embraces 16 holes or a hole to every 2-1/2 acres. If deposits are irregular in grade or thickness, intermediate holes are drilled. Land-acquisition drilling embraces 2, 4, or 8 holes to each 40-acre tract. For more details see Johnson,[11] Mansfield,[12] and Fulton.[13]

A prospect map should show the following for each hole drilled: (1) Thickness of overburden; (2) thickness of matrix; (3) long tons of phosphate

---

[9] See footnote 3, p. 2.

[10] See footnote 7, p. 4.

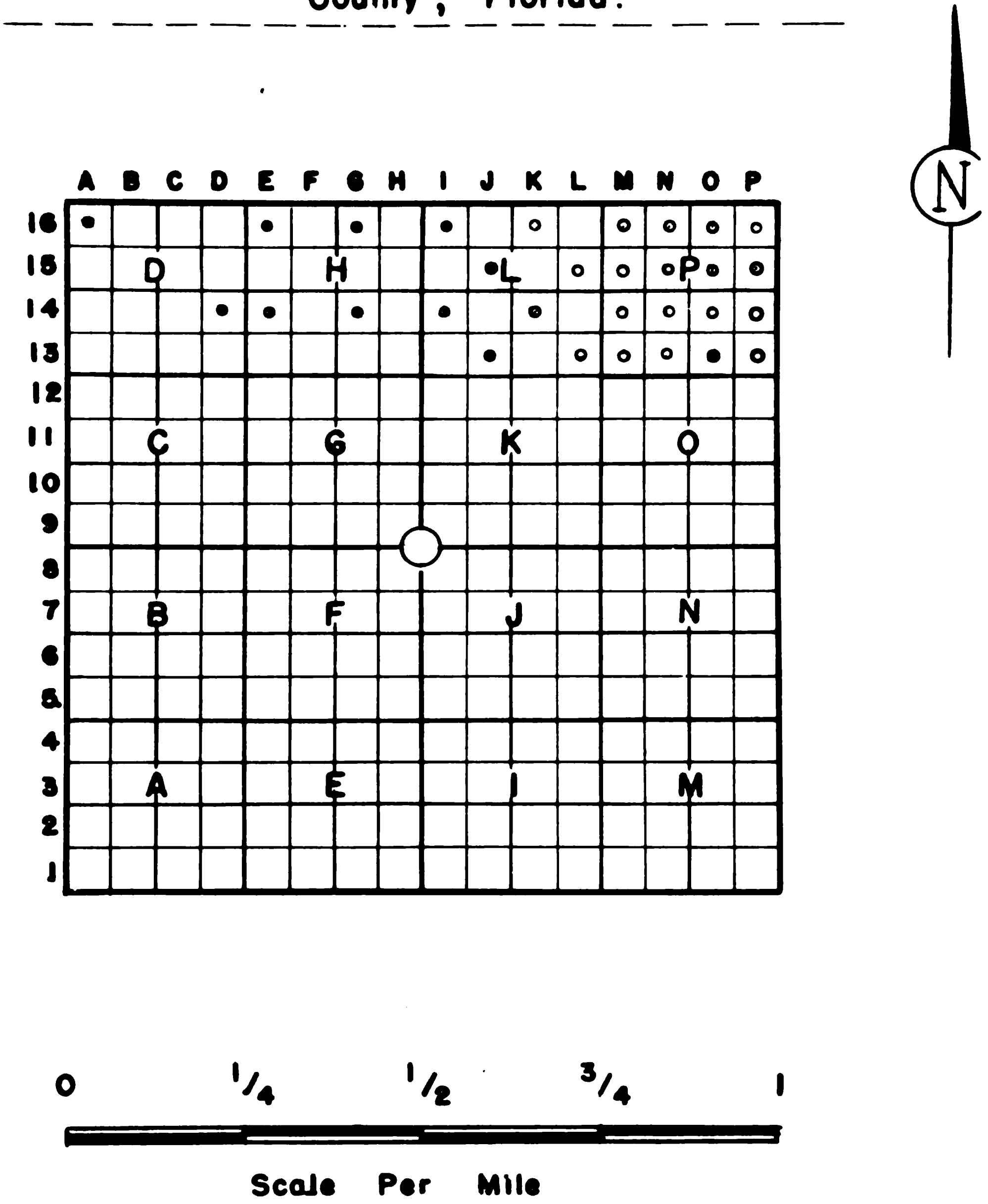
[11] Johnson, Bertrand L., Phosphate Rock. Part I: Bureau of Mines Inf. Circ. 6256, 1930, 64 pp.

[12] Mansfield, George R., Phosphate Resources of Florida: Geol. Survey Bull. 934, 1942, 82 pp.

[13] See footnote 3, p. 2.

Section- , Township- -S., Range- -East.

County, Florida.



Note

Sketch Shows 2, 4, 8, and 16 Hole Patterns for each Forty Acre (40-A.) Tract.

Figure 4. - Drilling pattern, land-pebble field.

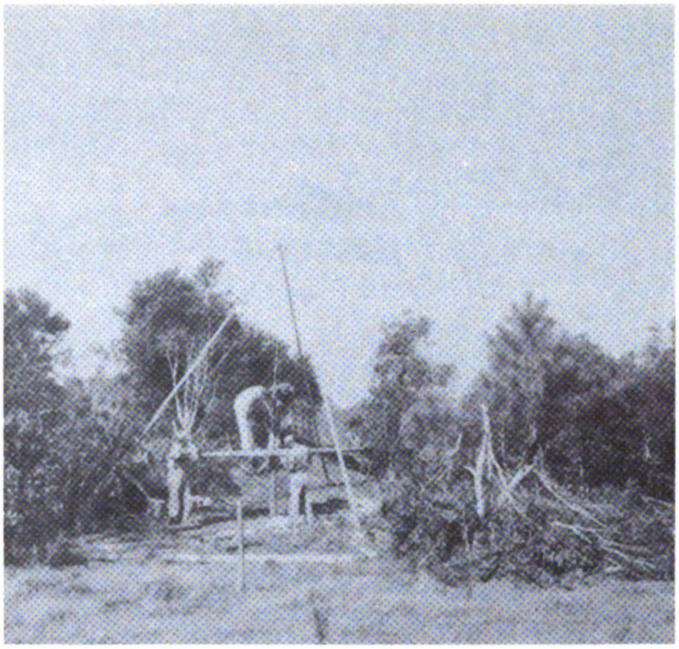


Figure 5. - Hand drilling in land-pebble area, showing drillers using post hole auger.

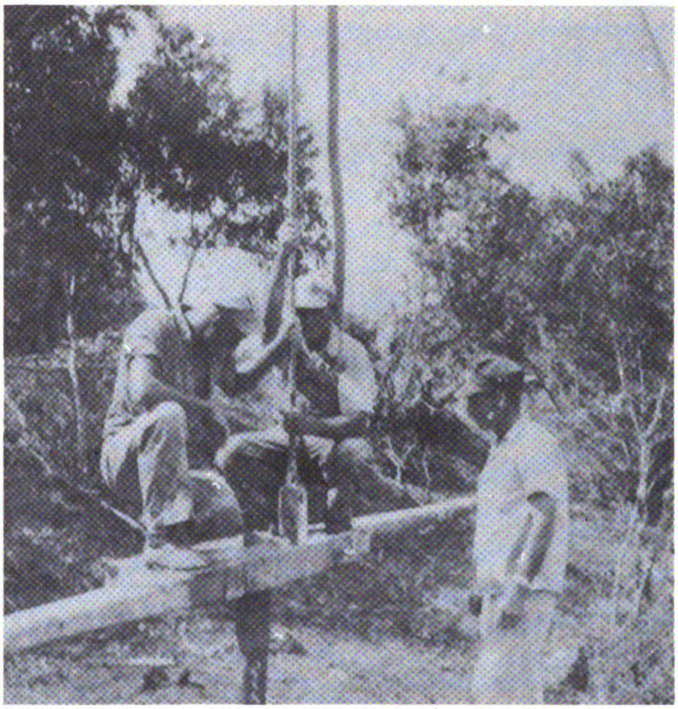


Figure 6. - Hand drilling in land-pebble field, showing type of auger used.

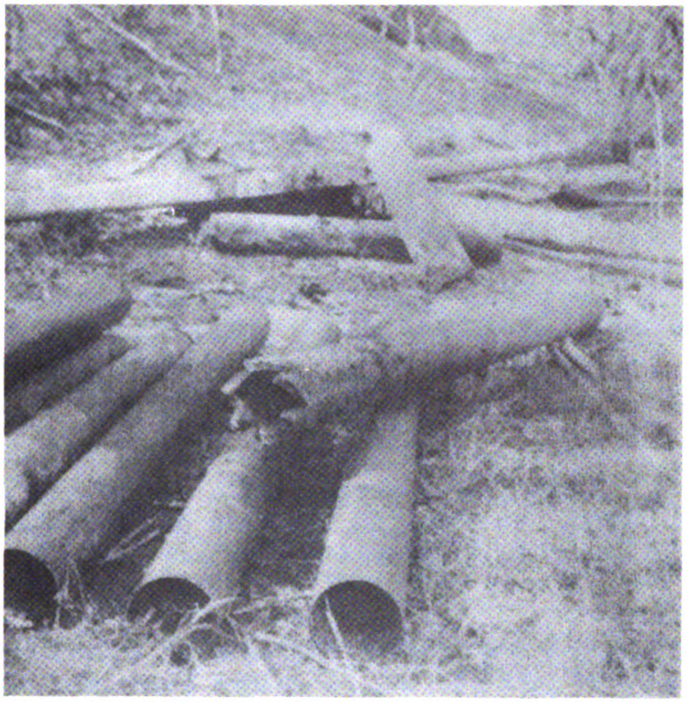


Figure 7. - Hand drilling in land-pebble field, showing $4\frac{1}{2}$-inch casing and "gun" (cutting shoe).

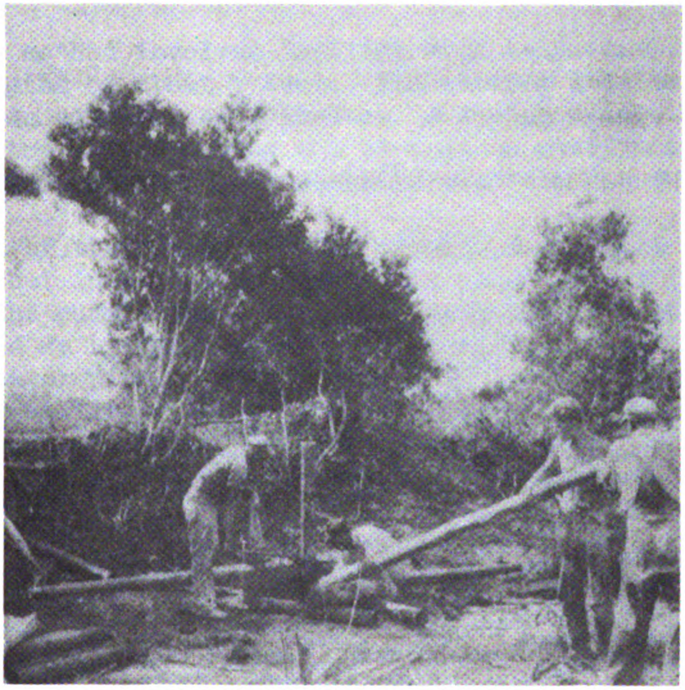


Figure 8. - Hand drilling in land-pebble field, showing drillers pulling casing with log lever and chain.

rock coarser than 3/64 inch or 14-mesh per acre with percentages of tricalcium phosphate, iron-aluminum oxides, and insolubles; and (4) long tons of phosphate rock finer than 3/64-inch or 14-mesh but coarser than 150-mesh, with percentages of tricalcium phosphate, iron-aluminum oxides, and insolubles.

Drilling Methods

The drilling methods employed at present comprise: (1) Hand-drilling with casing, auger, and sand pump; (2) power-drilling with rotary core drill; and (3) drilling with a power auger.

Hand Drilling

Hand drilling has become standardized (figs. 5-8). It is the only practical method developed to date for drilling in swamps, flooded areas, wooded sections, and other places inaccessible for motor or horse-drawn transport.

Four companies employ this method exclusively for exploration and final sampling, and three companies employ it for checking and final sampling purposes and for exploration in areas where power drilling is impracticable.

Hand-drilling operations are carried out with three- and four-man crews, and service trucks are furnished for moving equipment and hauling drillers to and from drilling areas.

Briefly, the method involves drilling with 4-1/2-inch flush-joint steel casing cut in lengths of about 5 feet. The cutting shoe is a saw-toothed bit with an outside diameter of 5 inches. A wooden clamp, 6 to 10 feet long, is bolted to the top of the casing and is used to oscillate the casing through a small arc; it also serves as an operating platform for two drillers.

The core cut by the casing is removed with a posthole auger attached to 3/4-inch pipe cut in 5-foot lengths. Wet sand and semifluid material are removed with a sand pump attached to a 1/2-inch rope. Hardpan and large pebbles are broken up by hand churn drilling with a chopping bit attached to the 3/4-inch auger pipe. A light tripod 18 to 20 feet high is erected over the hole to facilitate handling long lengths of auger pipe. The casing is pulled by two or more men operating a long pry pole over a log or casing fulcrum. A steel chain is looped around the casing and attached to the end of the pry pole.

This method is explained in detail by P. V. Roundy.[14]

Equipment

2 - 4-inch, posthole augers, 9 inches long, threaded for 3/4-inch
standard black-iron pipe.
75 feet, 3/4-inch pipe.

---

[14] See footnote 7, p. 4.

2 - Auger handles threaded for 3/4-inch pipe.

2- Rock bits, threaded for 3/4-inch pipe.

2- Sludge or sand pumps, 3-1/2 inch O.D. x 30 inches, with bottom flap valve and bail on top.
100 feet, 1/2-inch manila rope.

75 feet, 4-1/2-inch, flush-joint steel casing.

2- Cutting shoes, with hard-faced saw teeth made from a 6-inch section of 4-1/2-inch casing with 5-inch-diameter cutting clearance (fig. 7).

1 - 4-1/2 inch casing cap with rounded edges to protect sand-pump rope and casing threads.

1 - Casing clamp (figs. 5-6). It is made from two 6- to 10-foot pieces of 4 x 6-inch lumber, which are overlapped 4 feet and bolted together on the 4-inch section with two 5/8-inch bolts; a hole for the 4-1/2-inch casing is cut through the center of the splice.

1 - Tripod made with 3-inch x 18 to 20 foot poles, bolted together at apex (fig. 5).

1 - 18- x 24-inch loop, made with 1/2-inch steel rod, attached to 1/2-inch tripod apex bolt (used to steady drill pipe)(fig. 5).

1 - 8-foot length steel chain; links 1/4 to 1/2-inch steel (used to lift casing out of the hole)(fig. 8).

1 - Casing pry pole 4 to 6 inches diameter x 10 to 12 feet.

1 - Pry-pole fulcrum 4 to 6 inches diameter x 4 to 6 feet, small tools and accessories.

Sampling. - General practice is to build up one or more samples from cuttings of minable matrix for each hole. Separate samples of questionable-grade matrix are taken. If matrix is separated by low-grade or barren beds, two or more samples are collected. One company divides all drill samples exceeding 15 feet of matrix into two samples of equal length. Common practice is to accept all samples, which have a recovery volume equivalent to 90 percent of the calculated volume of the hole, sometimes referred to as theoretical volume.

Wooden core boxes are used by some operators to save all cuttings of the matrix regardless of apparent phosphate content. Sample lengths are marked in core boxes, in the field, for each change of matrix. This procedure provides information from which to determine the distribution of phosphate in the matrix beds.

Preparation of Sample. - The following is an outline of common practice in the land-pebble field:

(1) Hold samples until excess water has drained off.
(2) Weigh total sample.
(3) Take moisture sample (5 pounds for samples weighing less than 100 pounds, and 10 pounds for samples weighing more than 100 pounds).
(4) Determine weight of material packed into a 1/2-cubic foot container.
(5) Mix total sample, or a weighed portion, with water for 15 to 20 minutes, then wash over 3/64-inch or 14-mesh slotted screen.
(6) Wash undersize over 1/32-inch or 20-mesh slotted screen.
(7) Wash undersize from (6) over 150-mesh screen.
(8) Wash minus 150-mesh to waste.
(9) Wash portions of matrix remaining on screens clean of clay, collect separately, weigh, and analyze.

Details of sampling are given in publication noted below.[15]

Calculation of Tonnage. - The Pratt or Meade method is generally used to calculate tonnage of phosphate pebbles per acre, based on drill-hole data and samples.

Pratt Method. - This method is based on the square feet per acre, thickness of phosphate matrix, weight of 1 cubic foot of matrix, and percentage of pebble content by weight in matrix. Therefore: (square feet per acre) x (thickness of matrix in feet) x (weight in lb. of 1 cubic foot of matrix) x (percent of contained pebbles in matrix) ÷ 2,240 = long tons of pebbles per acre. This method, or a modification thereof, is generally accepted by the operating companies.

Meade Method. - This method is based on the number of square feet per acre, area of drill hole in square feet, and actual total weight of phosphate pebbles recovered from drill-hole sample. Therefore: (square feet per acre) x (actual weight of pebbles in lb. recovered from drill-hole sample) ÷ (area of drill hole in square feet) x 2,240 = long tons of pebbles per acre.

Power Drilling (Rotary Core and Mechanical Auger)

Rotary core drilling was started by one company on an experimental basis in 1943. Several different types of core barrels were employed in an effort to secure undisturbed cores of various types of matrix. None of the barrels proved satisfactory for all conditions encountered in the field and experiments were abandoned in favor of mechanical augering with rotary core drill rig.

---

[15] Association of Florida Phosphate Mining Chemists, Florida Land Pebble Phosphate Industry, Methods Used and Adopted: 1938.

Details of rotary core experiments are given by James A. Barr.[16]

Mechanical Augering. - In October 1947, the writer visited the drilling area and the following information is based on his observations:

Mechanical augering involves the use of a specially designed, hollow auger-type, core-barrel (figs. 9-11), built from 3-5/8 inch I.D. x 4-1/4 inch O.D., steel casing. The barrel is 4 feet, 4 inches in length with an N-rod adapter attached to the top. Two short cutting flights are built inside the barrel on the bottom end. This barrel is used with standard rotary drill-rig equipment as distinguished from the power auger.

Drilling a hole follows the standard procedure of core drilling using a 15-foot Kelly bar, with the exception that the drilling is done dry. After one 2-1/2-foot interval is drilled the rods and core barrel are removed, and the core is extracted. The core barrel is then washed to the bottom of the hole and the next 2-1/2-foot interval drilled dry. Successive 2-1/2-foot drill runs are made until the hole has been drilled to the required depth.

Since no casing is used, the hole has to be washed clean of caved material before a core run can be drilled. The barrel provides for 2-1/2-foot drill run of disturbed core and extra space for heavy material, caved into the hole between runs, which is too heavy to be washed off the bottom.

The core is extracted from the barrel by removing the adapter and up-ending the barrel. If the core is compacted or bound in the barrel it is freed by attaching the adapter, up-ending the barrel assembly, and bumping it repeatedly on the extractor block. The caved material left in the hole from the previous run is removed from the core barrel by hand and discarded; the following core is placed in a wooden core box and logged. Total recovered core is saved and sent to the sampling plant where preparation of a sample is similar to that explained under hand drilling.

Water is conserved by recirculating the sludge collected in a small sump, dug near the collar of the hole.

The writer estimates that, under average working conditions, four 45-foot holes can be drilled in an 8-hour shift with a disturbed core recovery above 80 percent.

The drill crew consists of a foreman, one driller, two helpers, and two samplers.

Equipment (figs. 9-10)

1 - Drill unit, Failing model 36, type C, with sliding base and equipped with 15-foot kelly bar; hydraulic feed with 2-foot - 6-inch run, hydraulic operated mast; and Gardner-Denver pump. All mounted on a Ford truck and operated by a power take-off.

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[16] Barr, James A. (chief engineer, International Minerals & Chemical Corp.), Symposium on Prospecting for Phosphate: Am. Inst. Min. and Met. Eng., Tech. Pub. 2089, quoting A New Core Barrel for Prospecting for Phosphate in Florida, by I. M. LeBaron.

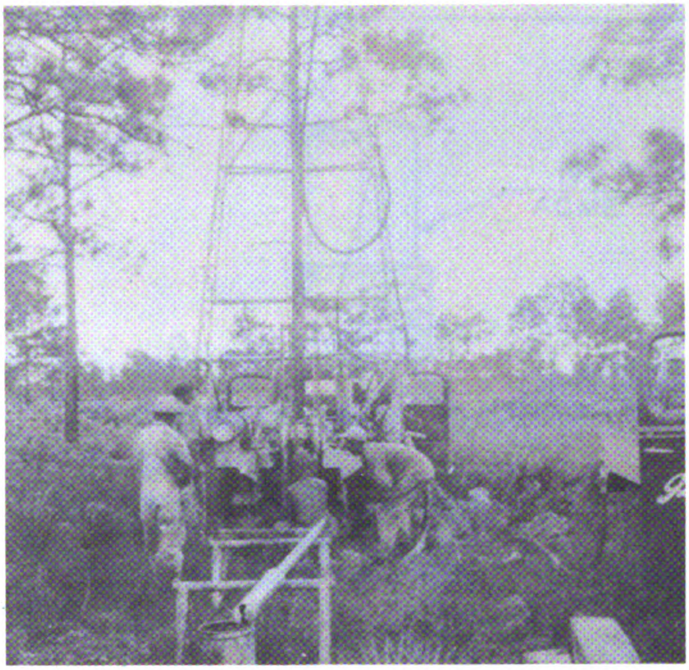

Figure 9. - Power drilling with Failing drill rig, land-pebble area, showing rig and part of water truck. (Auger-type core barrel, fig. 11, in foreground.

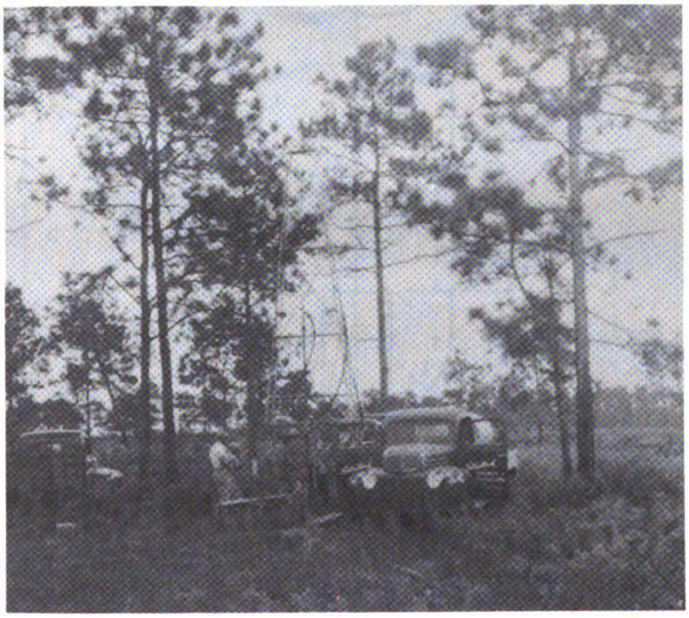

Figure 10. - Power drilling unit, land-pebble field, showing service truck, drill rig, and water truck.

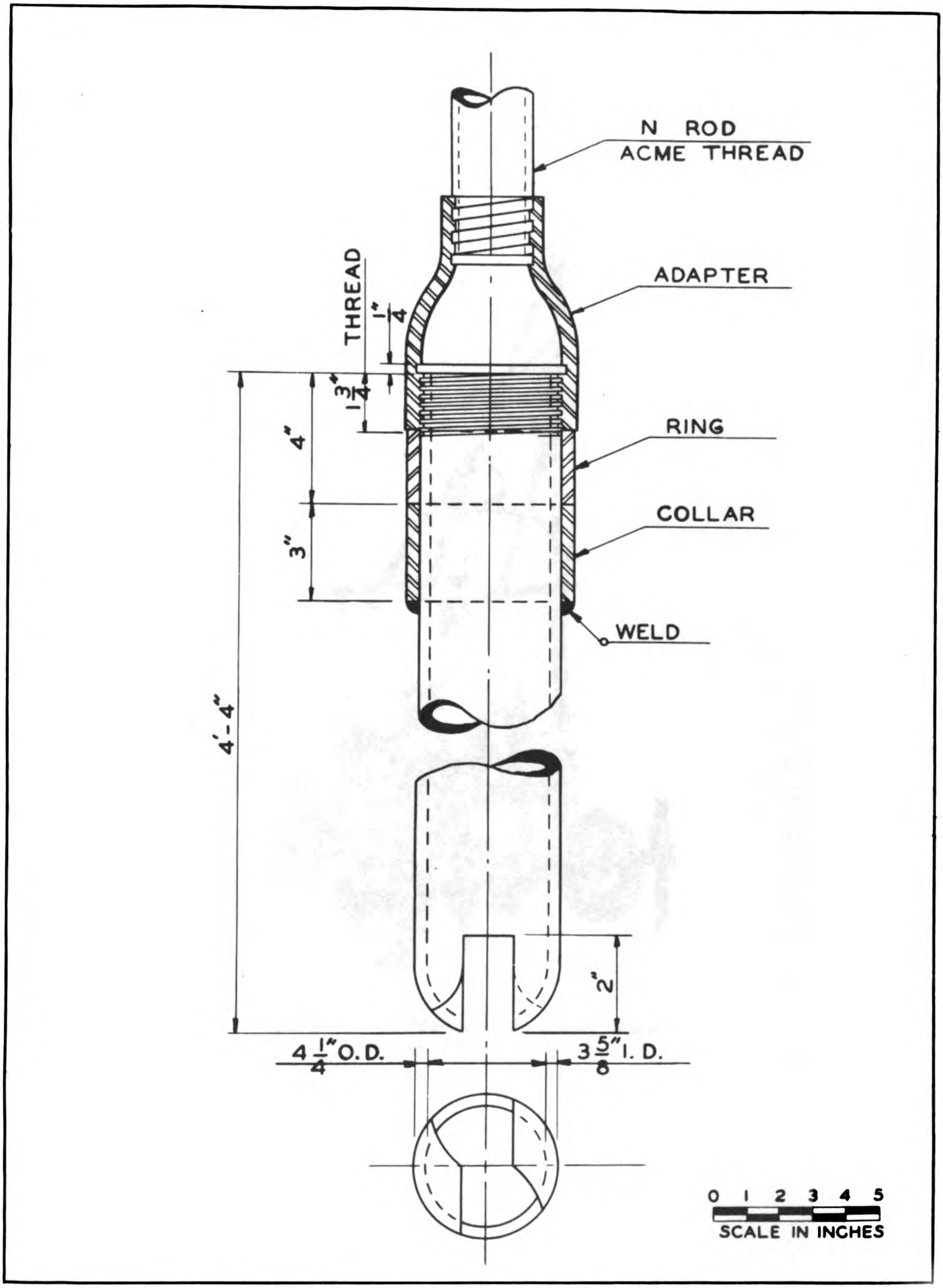

Figure 11. - Auger-type core barrel.

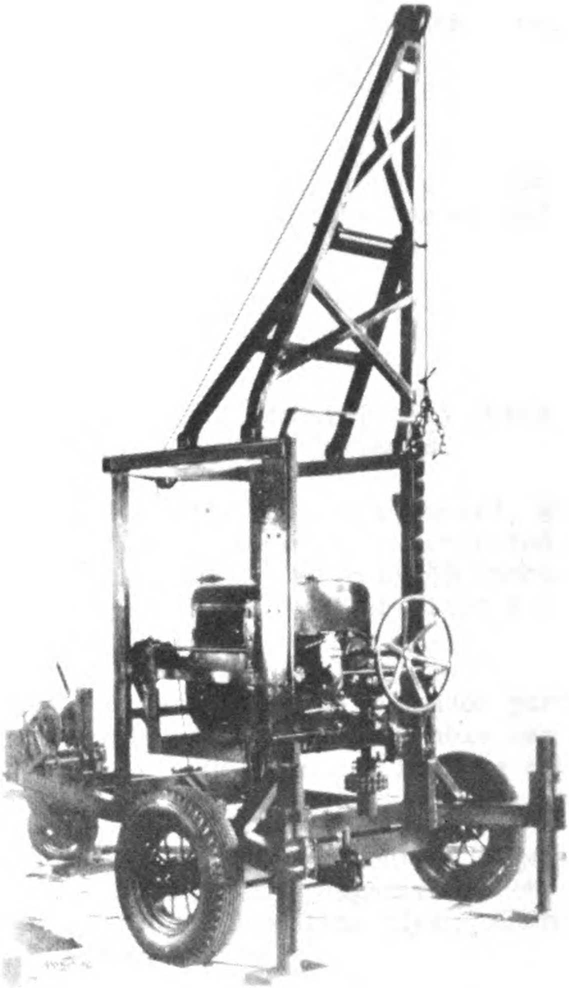

Figure 12. - "Parmanco" power auger drill.

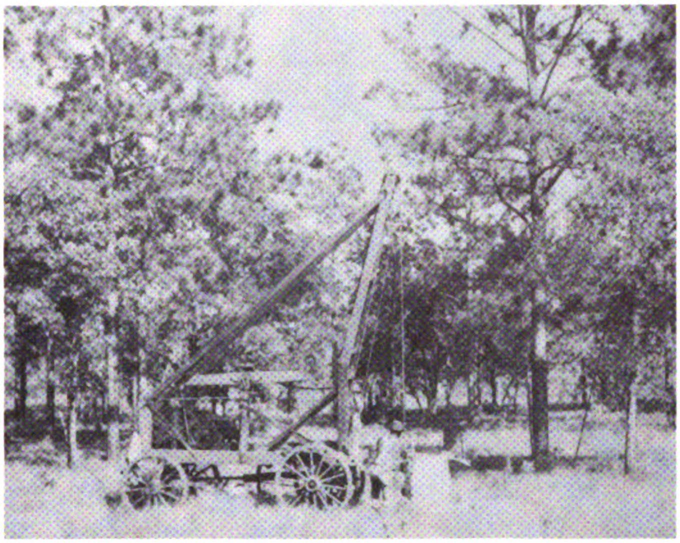

Figure 16. - Hard-rock field; churn drill mounted on wagon gear.

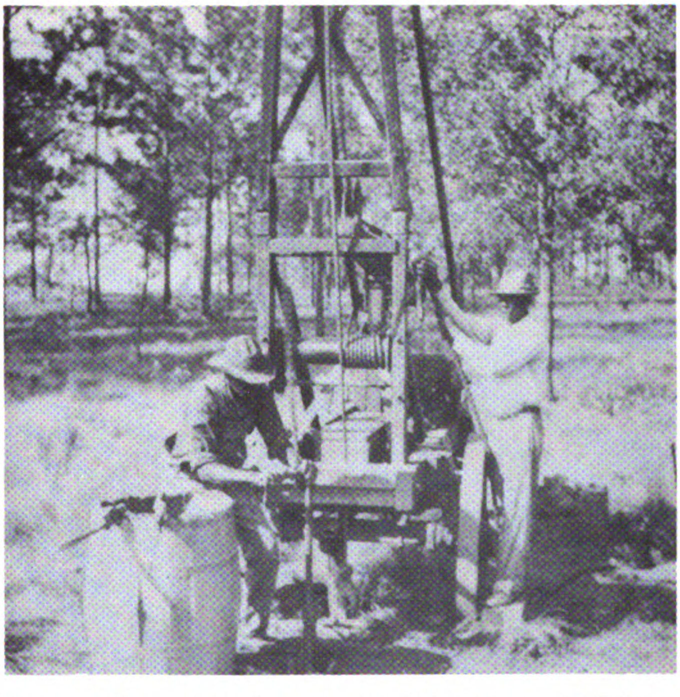

Figure 17. - Hard-rock field; "jet drilling" (churn drilling with jet bit, figs. 18 and 19.)

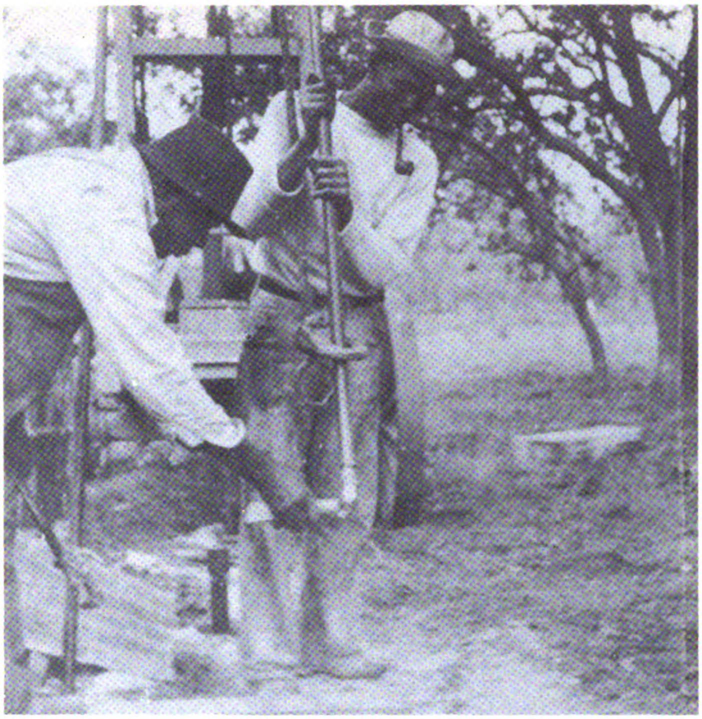

Figure 18. - Removing cuttings from drill pipe.

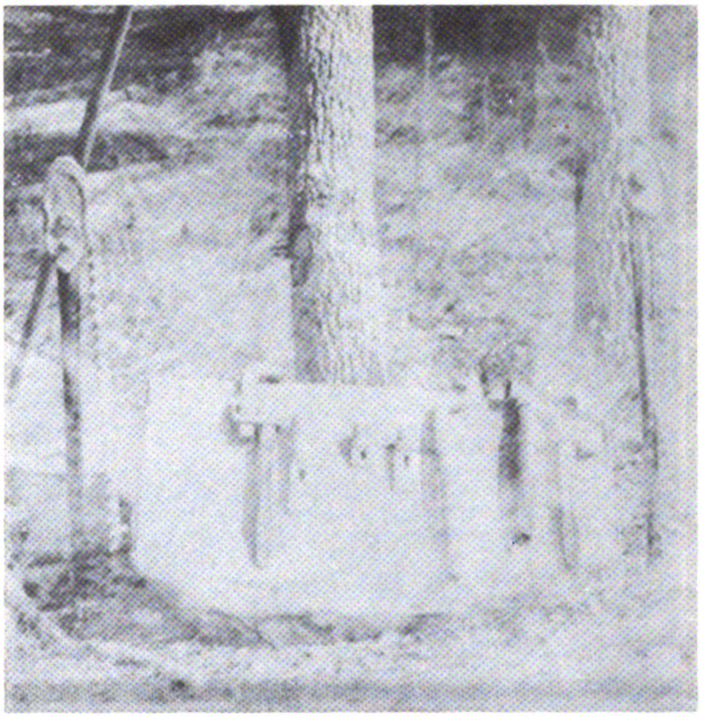

Figure 19. - Drilling tools; showing wrenches, jet bits, pipe lifter, and goose neck.

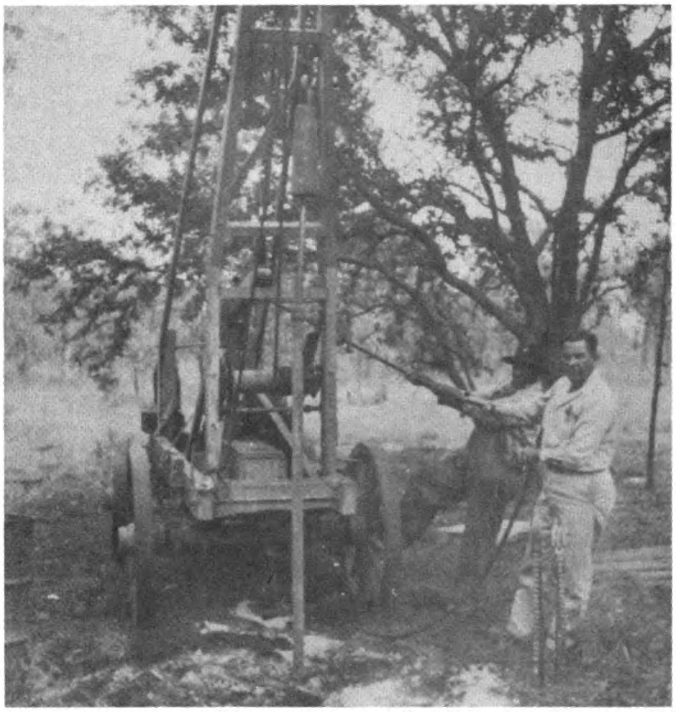

Figure 15. - Hard-rock field; driving 2-inch casing.

Land-Pebble Field

Hand Drilling

No. of crews	No. of men per crew	Foreman-hr. per crew for 8-hr. shift	Average footage drilled per crew for 8-hr. shift	Man-hr. per foot
2	4	4	46	0.78
2	4	4	45	.80
2	4	4	40	.85
4	3	2	50	.52
2	3	4	33-2/3	.87
3	3	-	40	.60
3	3	-	42-1/2	.56
Average on daily basis			43.1	.74

Estimated Life of Equipment (average depth of hole - 43 ft.)

Part	No. of holes	Years	Consumption, feet per foot of hole drilled.
Steel casing, 4-1/2 in., 75 ft.	500	3-1/2	0.0035
Drill pipe, 3/4 in., 75 ft.	250	1-3/4	0.0070
Sand pump	250	1-3/4	-
Tools and accessories	250	1-3/4	-
Post-hole augers	75	1/2	-

Power Drilling (Mechanical Augering)

No costs of any kind or performance records were available for this work.

Estimating the completion of four 45-foot holes per 8-hour shift, the labor costs would be equal to 0.27 man-hour per foot of hole.

Power Drilling with Auger

No detailed costs or performance records were available for publication.

It is estimated, under normal operating conditions, that a two-man crew can complete six 50-foot holes per 8-hour shift, including four-hours supervision of foreman. This is the equivalent of 0.067 man-hour per foot of auger hole.

Hard-Rock Field

Cupping and Churn Drilling

Using average unit performance of 80 feet of drilling per 8-hour shift, including 2-2/3 hours each for prospector and key man, labor costs are equal to 0.27 man hour per foot of hole.

Total average cost was reported to be 32-1/2 cents per foot of hole.

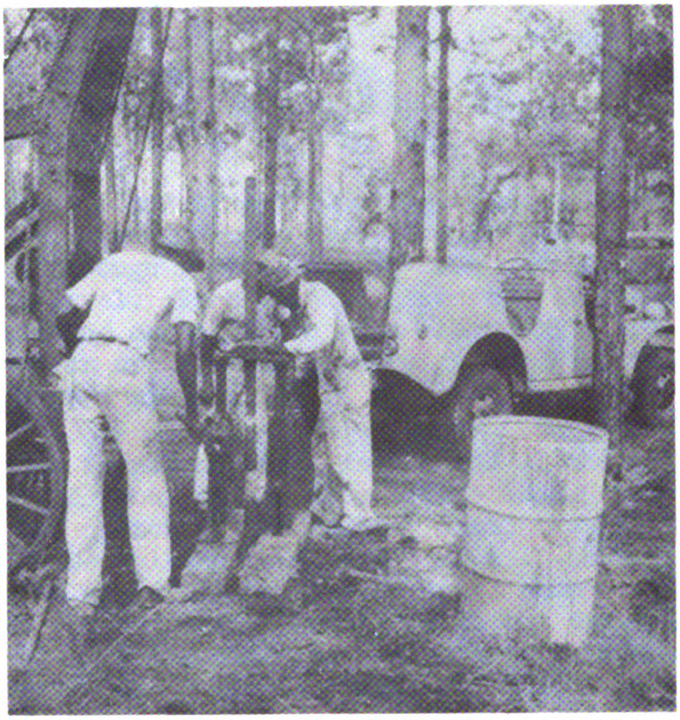

Figure 20. - Hard-rock field; pulling casing with 15-ton railroad jacks. (Command car in right center.)

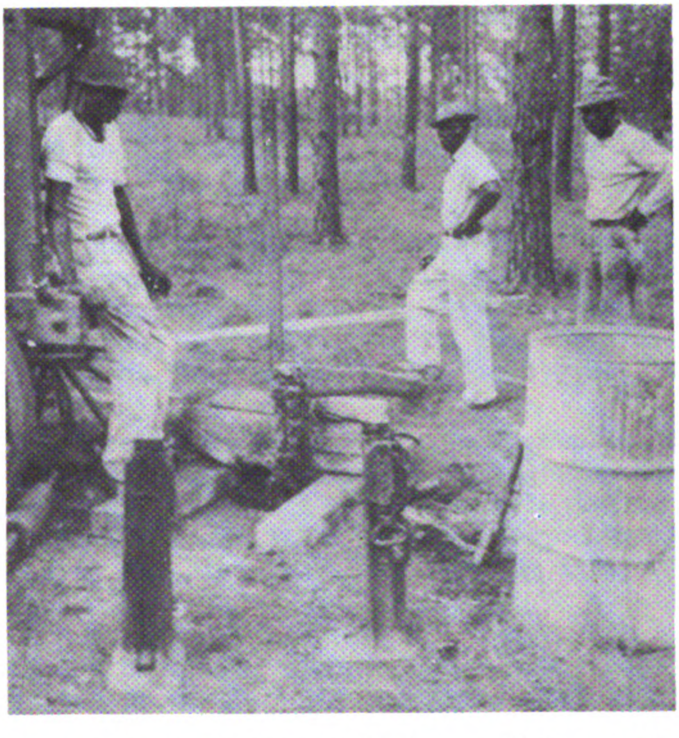

Figure 21. - Hard-rock field; pulling casing with log lever and chain.

The cuttings held in the drill pipe (fig. 18) constitute the sample for each 2-1/2-foot run. If a composite sample is desired the sludge jetted out of drill pipe can be saved, screened, analyzed, and balanced with the analysis of the cuttings recovered at the jet drill bit.

To carry out this method of drilling, small churn drills (figs. 15 - 18) mounted on two-mule-type wagons are employed. These drills have 8-foot walking beams, effective through 7 feet, and 15-foot head frames that rise about 18 feet above ground level. Each unit is powered with a 3 h.p. Fairbanks, single-cylinder, gasoline engine which runs about 450 r.p.m. and is geared down to the walking-beam drive wheel at a ratio of 11:1, thus providing for about 42 2-foot strokes a minute.

The drilling rope is not attached to the end of the walking beam; instead, it extends from a fixed spool on the side of the head frame through an 8-inch pulley attached to the center of the walking beam, then through a 6-inch-stroke pulley on the end of the walking beam, and over a 10-inch sheave wheel in the head frame and down to the drilling pipe or drive hammer. The drill-rope arrangement provides for adjusting the stroke to any desired length between 0 and 2 feet by regulating the slack in the rope between the fixed spool and the drill pipe or drive-hammer (figs. 15-17).

A hand winch, with a reduction-gear ratio of about 2:1, is bolted to the upright members of the head frame.

An "Army" command car with a trailer-hitch attachment is used to move the drills from one location to another and to take the place of a service truck (fig. 20).

Casing is pulled by employing railroad jacks until it is free; the log-lever and chain method is then used until the string is loose enough to be pulled by the hand winch (figs. 20 and 21).

Three churn-drill units are operated under the direct supervision of an experienced drill prospector. The drilling crew consists of a driller and a helper (rope holder) for each unit, with a key man to make on-the-job repairs and keep all units operating. It is estimated that each drill unit crew will complete an average hole, 80 feet in depth, for each 8-hour drill shift.

Since mining practice in the hard rock field usually involves removal of overburden by hydraulic methods, followed by mining the matrix under water by dragline above water level, all drill holes are extended to a depth of 35 to 40 feet below water level, the limit of mining, or to limestone which bottoms phosphate occurrences in the district. The maximum depth of holes drilled is 100 feet.

All drill holes are carefully logged. Matrix cuttings for each 2-1/2-foot run are inspected by the prospector and estimated grades thereof recorded. Estimates of grades of phosphate are checked by analyses of samples.

Drilling Pattern

The general drilling pattern is shown in figure 22. Complete sampling of a 40-acre tract embraces about 676 holes or about 16 to an acre. Prospect drilling embraces about 100 holes to 40 acres; when matrix is discovered the drilling pattern is completed on 16-holes-to-an-acre basis.

Prospect maps are prepared on a scale of 50 feet to 1 inch. Coordinates are laid out with zero at the northeast corner of each 40-acre tract. East-west coordinates are numbered from 1 to 26, and north-south coordinates are lettered from A to Z. A completed prospector's map shows depth of water level; cubic yards of overburden above and below water level; and cubic yards of matrix and tons of phosphate, with estimated grades above and below water level. For details, see Mansfield.[18]

Equipment

Unit drilling equipment embodies the following:

1 - Wagon-mounted churn drill.

100 feet - 2-inch drill casing, 5-foot lengths.
100 feet - 1-inch drill pipe, 5-foot lengths.
50 feet - 3/4-inch drill pipe, 5-foot lengths.

3 - Jet drill bits (fig. 19).

20 feet - 3/4-inch manila rope.
35 feet - 1-inch manila rope.

1 - Drive hammer, 155 lb., 18 inches long, with 5-foot, 1-inch round guide bar with forged eye for drilling rope.

1 - Cup digger (fig. 14). A slotted 10-inch section of 3-1/4-inch steel casing, with a tempered cutting edge on the bottom, is fitted around and riveted to two prongs of a 10-inch fork made from 1/2-inch-square, steel-bar stock. The fork handle is welded into a 2-foot section of 1-inch pipe, fitted with a reducer to 3/4-inch pipe.

4 - Jacks, railroad Joyce, 15-ton (for 3-drill units to raise 2-inch casing).

2 - 2-inch casing clamps for use with Joyce jacks.

1 - 55 gal. water drum (plus 2 spares for 3 units).

Small tools and accessories.

COSTS

Detailed drilling costs and actual performance records were not available for publication; therefore, only average costs in man-hours will be shown in this paper for the land-pebble area, and total average cost per foot for the hardrock field, as follows:

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[18] See footnote 12, p. 6.

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County , Florida.

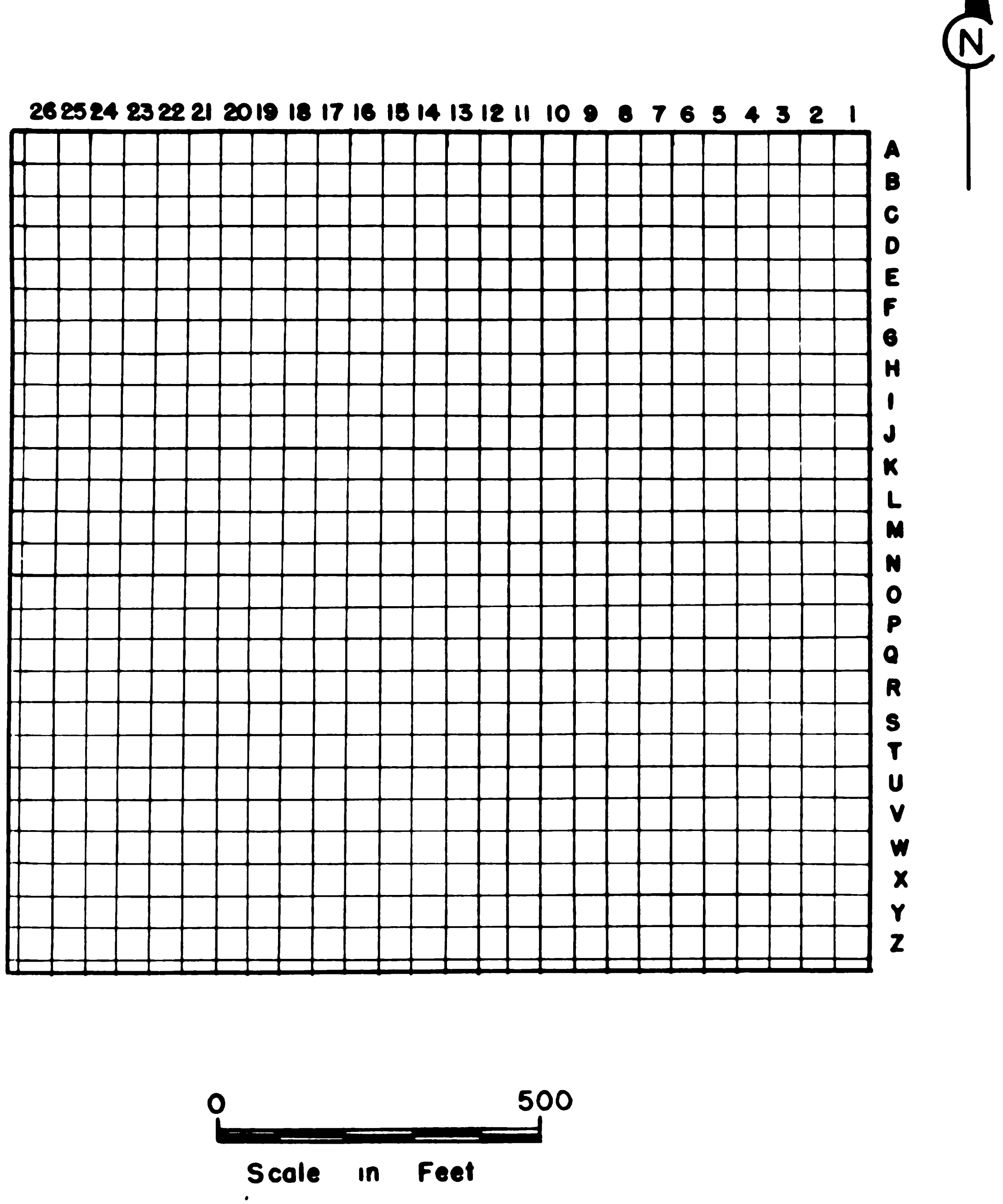

Figure 22. - Drilling pattern, hard-rock field.

Land-Pebble Field

Hand Drilling

No. of crews	No. of men per crew	Foreman-hr. per crew for 8-hr. shift	Average footage drilled per crew for 8-hr. shift	Man-hr. per foot
2	4	4	46	0.78
2	4	4	45	.80
2	4	4	40	.85
4	3	2	50	.52
2	3	4	33-2/3	.87
3	3	-	40	.60
3	3	-	42-1/2	.56
Average on daily basis			43.1	.74

Estimated Life of Equipment (average depth of hole - 43 ft.)

Part	No. of holes	Years	Consumption, feet per foot of hole drilled.
Steel casing, 4-1/2 in., 75 ft.	500	3-1/2	0.0035
Drill pipe, 3/4 in., 75 ft.	250	1-3/4	0.0070
Sand pump	250	1-3/4	-
Tools and accessories	250	1-3/4	-
Post-hole augers	75	1/2	-

Power Drilling (Mechanical Augering)

No costs of any kind or performance records were available for this work.

Estimating the completion of four 45-foot holes per 8-hour shift, the labor costs would be equal to 0.27 man-hour per foot of hole.

Power Drilling with Auger

No detailed costs or performance records were available for publication.

It is estimated, under normal operating conditions, that a two-man crew can complete six 50-foot holes per 8-hour shift, including four-hours supervision of foreman. This is the equivalent of 0.067 man-hour per foot of auger hole.

Hard-Rock Field

Cupping and Churn Drilling

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